

BENEATH THE FLAVOUR: UNVEILING THE CARCINOGENIC RISK FROM CONSUMPTION OF DRIED FISH– A SYSTEMATIC REVIEW

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ABSTRACT

Aim and Background: Dried fish is widely consumed as an affordable, nutrient-rich protein source with a long shelf life, particularly in developing regions. However, traditional drying and smoking practices can introduce hazardous contaminants, including aflatoxins, polycyclic aromatic hydrocarbons (PAHs), heavy metals, and fungal toxins, many of which possess carcinogenic potential. Poor hygiene, open-air drying, and improper storage further exacerbate microbial growth and toxin accumulation, raising significant public health concerns. This systematic review aims to evaluate the major contaminants in dried fish and their associated carcinogenic risks.

Materials and Methods: A systematic review was conducted in accordance with PRISMA guidelines. Electronic databases including PubMed, ScienceDirect, Cochrane Library, ResearchGate, and Google Scholar were searched for English-language, peer-reviewed studies published from 1990 onwards. Eligible studies assessed chemical or biological contamination in dried fish or examined associations between dried fish consumption and cancer risk. Of 300 records screened, 34 full-text articles were assessed, and 4 studies met the inclusion criteria.

Results: All included studies reported contamination linked to carcinogenic risk. Aflatoxin B1, a Group 1 carcinogen, was detected in up to one-third of samples. Heavy metals such as cadmium, lead, and mercury frequently exceeded permissible limits, while smoked fish showed higher PAH concentrations. Epidemiological evidence indicated an increased lung cancer risk among frequent consumers (OR \approx 2.83), with children exhibiting the highest estimated lifetime cancer risk.

Conclusion: Improperly processed or stored dried fish represents a potential source of dietary carcinogen exposure. Strengthened regulation, improved processing practices, and public awareness are urgently required to protect public health while preserving the cultural importance of dried fish.

Introduction

Fish is a valuable source of high-quality animal protein, it is appreciated for its relatively low levels of low-density lipids and it has abundance of vitamins, antioxidants, and polyunsaturated fatty acids [1,2]. Since fish spoils quickly, methods that remove moisture particularly dehydration are often employed to extend shelf life [3,4,5]. Among the various preservation strategies, drying is the most common and effectively maintains beneficial nutritional properties. This approach ensures that preserved protein remains available [3]. This is significant in rural areas in underdeveloped countries where it's hard to get refrigeration [6,7]. Fish drying is seen as a cheap and effective way to do things in many parts of Europe and Asia [8,9]. Sun drying is a commonly used method that utilizes solar heat energy and wind to speed up the evaporation process from fish [10]. This process inhibits microbial activity and provides distinct texture, flavor, and coloration [8,9]. In periods when fresh fish is unavailable, dried fish offers an accessible and cost-effective source of protein and essential minerals [6,7]. Compared to fresh fish, the dried form typically contains higher protein and fat levels, making it a more concentrated nutrient source [8,9]. Nutritionally, it is notable for its richness in omega-3 fatty acids, antioxidants, and a protein content ranging between 80% and 85%, which exceeds that of fresh

fish^[6,7]. Along with plant-based protein sources, dried fish is an excellent alternative to meat because of its high content of nutritious fats and proteins^[3].

Despite these benefits, in many cases the issue of safety related to dried fish is still very much a concern which we attribute to the pre dominance of traditional drying processes. We see mainly three issues at play microbial contamination, heavy metal pollution and use of chemical preservatives^[3]. Also of note is the fact that long term exposure to polycyclic aromatic hydrocarbons (PAHs) has been associated with many types of cancer which include but are not limited to those of the gastrointestinal tract, the lungs, the bladder and the skin^[11,12]. These pollutants are to be found in smoked or smoke-dried fish which see variable levels of them based on environment and smoking methods. PAHs put in at any stage of a fish's life which also sees them accumulate in lipid rich organs like the liver or in some invertebrates the hepatopancreas^[11,13].

Poor handling and storage practices in developing countries increase the risk of microbial spoilage and toxin production in dried fish^[1,14]. Harmful compounds such as mycotoxins and total volatile basic nitrogen (TVB-N) can cause illnesses ranging from food poisoning to liver cancer^[3,15]. Common fungal contaminants *Aspergillus*, *Penicillium*, and *Fusarium* produce mycotoxins that, when consumed in significant amounts, may lead to severe health problems, including immune system disorders and respiratory illnesses^[3,15]. Aflatoxins, found worldwide in food products, are among the most potent of these toxins and are both immunosuppressive and carcinogenic^[16]. The International Agency for Research on Cancer (IARC) identifies aflatoxin B1 as a leading cause of liver cancer and immune suppression, also associating it with jaundice, cirrhosis, and miscarriage^[1,17,18].

Another hazard stems from the accumulation of heavy metals like cadmium (Cd) and lead (Pb), which may originate from contaminated water before drying^[3]. These pollutants not only lower product quality but also present a moderate-to-high risk of cancer when ingested^[19,20,21]. Children are especially susceptible, with potential effects including neurological impairment, kidney and liver damage, cardiovascular disease, and reproductive toxicity^[1,22].

Chemical contamination might occur during the drying process as well. During open-air drying, some organochlorine pesticides like DDT and Heptachlor are used on fish to control insect damage. Although these pesticides are effective against the pests, they also pose great risk to the health of humans^[3]. Approved preservatives pose great risk to health as well when used in large amounts^[3]. Consumption of dried fish that contain pesticide residues has been associated with several illnesses, such as leukemia, different forms of cancer, epilepsy, infertility, damage to the liver and kidneys, immune suppression and system, and several others^[19,23,24].

The presence of PAHs, heavy metals, and mycotoxins in dried fish raises significant concerns regarding its safety and potential carcinogenic effects. This review aims to explore the key contaminants and their associated carcinogenic risks from consumption of dried fish emphasizing the urgent need for robust safety measures and regulatory interventions to safeguard public health.

Materials and Methods:

Study Design

This systematic review was conducted to examine the association between dried fish consumption and cancer risk, with a particular focus on contamination, chemical alterations during processing, and

resulting health concerns. The review evaluates published evidence on toxicological profiles, environmental pollutants, and carcinogenic potential related to dried fish.

Search Strategy

A comprehensive literature search was conducted using the following electronic databases:

- PubMed
- ScienceDirect (Elsevier)
- Cochrane Library
- ResearchGate
- Google Scholar (for grey literature and supplementary sources)

The search strategy combined keywords and Boolean operators as follows:

"dried fish and cancer" OR "fish contamination and health risks" OR "toxic metals in dried seafood" OR "aflatoxins in fish" OR "histamine levels in dried fish"
Combined with: ("cancer" AND "dried fish") OR ("health risks" AND "fish contamination")

Filters applied:

- English-language studies
- Human subjects
- Peer-reviewed articles

Manual screening of reference lists was performed to identify additional eligible studies not retrieved through database search.

Eligibility Criteria:

Inclusion Criteria

- Focused on dried fish processing, contamination (e.g., histamine, heavy metals, aflatoxins), and its potential link to cancer risk.
- Investigated consumer awareness, environmental health risks, or risk mitigation strategies relevant to dried fish.
- Assessed health effects associated with the consumption of dried fish or identified pollutants of known or suspected carcinogenicity.
- Published as original research articles in peer-reviewed journals.
- Published from January 1990 onwards.
- Conducted in human populations.

Exclusion Criteria

The following studies were excluded:

- Research not addressing dried fish or unrelated to cancer.
- Animal studies or in vivo experiments without direct relevance to human health.
- Articles with unclear methodology or insufficient data for assessment.
- Opinion pieces, editorials, anecdotal case reports, and non-peer-reviewed sources.
- Studies evaluating the general safety of seafood without specific reference to dried fish.

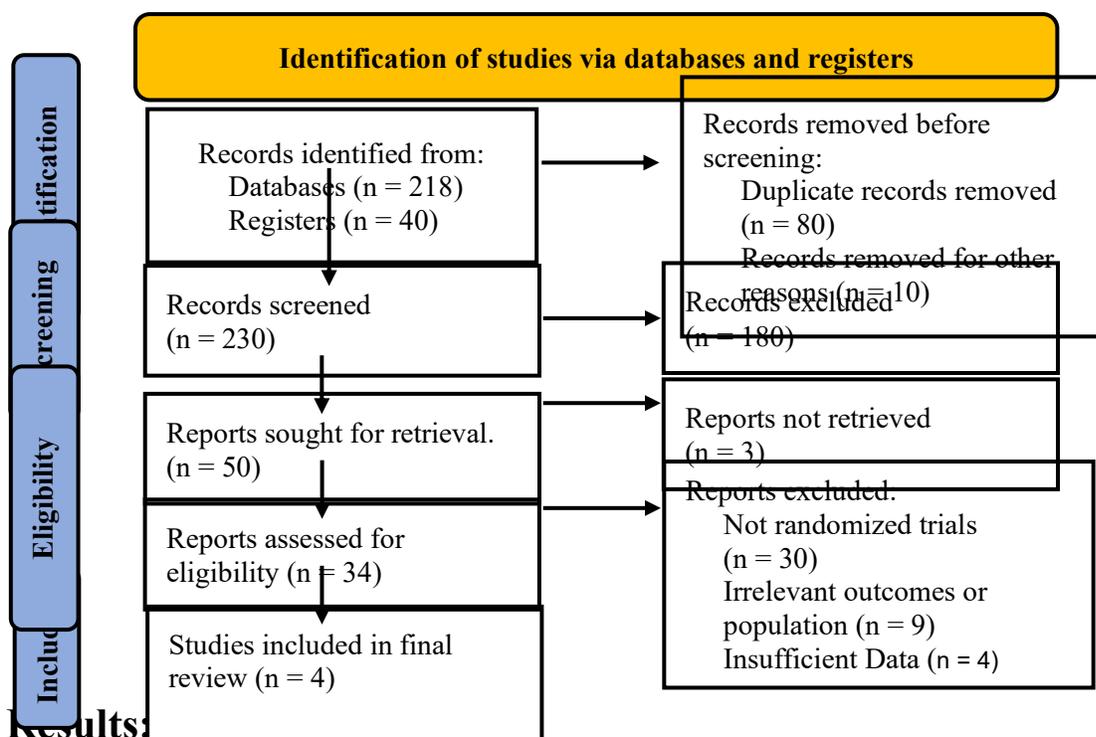
Study Selection Process

A two-stage screening process was followed:

1. Title and abstract screening to identify potentially eligible studies.
2. Full-text review of selected articles based on inclusion/exclusion criteria.

Duplicate records were removed prior to screening. The PRISMA 2020 flow diagram (Figure 1) summarizes the selection process.

Figure 1: PRISMA 2020 flow diagram for newly conducted systematic reviews that solely involved database and registration searches



This research resulted in 300 Articles from which 34 were full-text articles having accessibility and are eligible for review. Ultimately, 4 Articles were chosen for inclusion in this systematic review.

Table 1: Characteristics of Interventions in the Study

S. No	Title and Author Name	Year	Sample Size	Patient Characteristics	Duration	Patient Allocation
1	Monascus ruber: Invasive Gastric Infection Caused by Dried Fish Consumption ²⁵ Xavier Iriart	2010	1 (Case Report)	Patient with gastric adenocarcinoma developed Monascus ruber fungal infection	Single Case	Linked to consumption of contaminated dried and salted fish

S. No	Title and Author Name	Year	Sample Size	Patient Characteristics	Duration	Patient Allocation
2	Assessing Health Hazards of Dried Fish Consumption from Coastal Markets ⁶ Md Faisal	2016	16 samples (4 fish species)	Modeled for adults (70 kg) and children (15 kg) based on estimated daily intake	October–November 2022	Observational environmental risk assessment
3	Dietary Factors and Lung Cancer Risk in Japanese ²⁶ T takezaki	2018	1045 cases, 4153 controls	Hospital-based case-control study on dried fish intake and lung cancer	1988–1997	Matched by age and sex, retrospective data collection
4	Simultaneous Quantification of Aflatoxins and Other Mycotoxins in Dried Seafood ²⁷ Yijia Deng	2023	40 dried seafood samples	Analytical study using LC-MS/MS to quantify mycotoxins in seafood	Cross-sectional lab analysis	Product-based sampling, not human allocation
5	Toxic Metals and Aflatoxins in Smoked-Dried Fish and Health Risk Assessment ¹ H Uguru	2024	15 smoked-dried fish species	Levels of Cd, Hg, Pb, and aflatoxins in smoked fish; health risk estimation	April 2022 to September 2022	Environmental study, non-interventional

Table 1 this table summarizes the key studies that examine the health risks of eating dried fish. The studies include individual case reports, population-based observational studies, and lab tests. There are differences in sample type, duration, and methods used. However, all studies point to the possible cancer risk linked to biological factors like fungal contamination, chemical factors such as polycyclic aromatic hydrocarbons, aflatoxins, and heavy metals, as well as environmental pathways connected to dried fish consumption.

Table 2: Characteristic of the Primary Outcomes and Results of Studies included in the current study

S. No	Title and Author Name	Year	Effect Measure	Result
1	Monascus ruber: Invasive Gastric Infection Caused by Dried Fish Consumption	2010	Case analysis of infection	<i>Monascus ruber</i> isolated from gastric tissue and consumed dried fish

S. No	Title and Author Name	Year	Effect Measure	Result
2	Assessing health hazards of dried fish consumption from coastal markets in a developing nation	2016	Carcinogenic Risk (CR) from Chromium (Cr) and Lead (Pb)	Dried fish contaminated with Cr and Pb presents long-term cancer risk for children.
3	Dietary factors and lung cancer risk in Japanese: with special reference to fish consumption and adenocarcinomas	2018	Women who ate dried fish often had nearly 3 times higher odds of getting lung cancer (OR = 2.83).	Highlighted need for proper storage and testing to mitigate health hazards
4	Simultaneous Quantification of Aflatoxin B1, T-2 Toxin, Ochratoxin A and Deoxynivalenol in Dried Seafood Products by LC-MS/MS	2023	Aflatoxin B1 in dried fish suggests liver cancer risk.	Confirmed presence of mercury, cadmium, lead, and aflatoxins in dried fish
5	Toxic metals and aflatoxins occurrence in smoked-dried fish and their health risks assessment	2024	Multivariate contamination analysis	Identified multiple sources of contamination and emphasized improved monitoring measures

Table 2 Presents the major outcomes and findings from key studies on the health effects of dried fish consumption. The evidence shows consistent contamination with heavy metals, including chromium, lead, mercury, and cadmium, along with mycotoxins, especially aflatoxin B1, which are known carcinogens. Epidemiological data indicate a strong link between regular dried fish intake and a higher risk of cancers, such as gastric and lung malignancies. These findings highlight the urgent need for stricter monitoring, better storage practices, and regulatory control to reduce the cancer risk associated with dried fish consumption.

Table 3: Quality assessment of all the included studies

S. N	Author (Year)	Rando mizati	Alloc ation	Com paris	Conf oundi	Exper iment	Bli ndi	Co mpl	Exposu re	Outc ome	Out com	No Ot
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o		on	Conc ealme nt	on Grou p	ng	al Condi tions	ng	ete Out come	Charac terizati on	Asse sment	e Rep orti ng	her Th rea ts
1	Monascus ruber											
2	Assessing health hazards of dried fish											
3	Dietfactor s and lung cancer risk in Japanese											
4	Simultane ous Quantifica tionAflato xin											
5	Toxic metals and aflatoxins (2024)											

Legend:

Probably low risk	Probably high risk	Definitely High Risk	Definitely low risk
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Bias Summary

Selection Bias: Moderate for some studies, non-randomized nature of observational research.

Detection Bias: Generally low, as most studies relied on objective lab-based assessments.

Reporting Bias: Low across studies, ensuring findings were fully presented.

Blinding: Not applicable since studies focused on environmental sampling rather than direct interventions

Discussion:

This review highlights that the dried fish is a significant source of a carcinogen. These harmful substances mainly come from environmental pollutants, poor preservation methods, and inconsistent processing standards. Many key studies address these issues.

In 2010, Xavier Iriart documented a rare but severe instance involving a gastric cancer patient who acquired an invasive fungal infection of the stomach caused by *Monascus ruber*, associated with the consumption of dried fish known locally as "pène" (*Serrasalmus rhombeus*)²⁵.

In 2016, Md Faisal revealed that heavy metal levels in dried fish surpass safety limits, raising the lifelong cancer risk from cadmium (Cd) and chromium (Cr) in species such as *Harpodon nehereus* (Bombay duck), *Trichiurus lepturus* (ribbon fish), *Amblypharyngodon mola* (mola fish), and *Penaeus affinis* (shrimp)⁶.

In 2018, it was found by T Takezaki that women who regularly consumed dried or salted fish (Harpodon nehereus, Trichiurus lepturus, Amblypharyngodon mola, Penaeus affinis) had nearly three times the likelihood of developing squamous cell and small cell lung cancer compared to those who ate it infrequently. This was shown by an odds ratio of 2.83, meaning a strong link between dried fish consumption and increased cancer risk²⁶.

In 2023, Yijia revealed that Aflatoxin B1 was found in 30.8% of dried fish samples (*Lutjanus sanguineus*) at levels ranging from 0.58 to 0.89 µg/kg; it is categorized as a Group 1 carcinogen associated with hepatocellular carcinoma, highlighting the potential cancer risk from consuming dried fish²⁷.

In 2024, the research evaluated by H Uguru that 15 types of smoked-dried fish, including freshwater species like Africa catfish, tilapia, moonfish, mudfish, stinging catfish, bullseye snakehead, silver butter catfish, striped catfish, striped bagrid catfish, and African weakly electric fish, as well as saltwater species such as Atlantic mackerel, herrings, horse mackerel, blue whiting, and white croaker. These fish were found to contain toxic metals (cadmium, lead, mercury) and aflatoxins, which are associated with a higher risk of liver cancer and, in the case of cadmium, lung cancer. Moonfish and catfish exhibited the highest levels of aflatoxins, making them particularly dangerous, especially for children¹.

Noor JJ et al. (2025) demonstrated that natural compounds like gingerol suppress cancer-promoting pathways and enhance tumor-suppressor activity. In contrast, toxins identified in traditionally dried fish have been shown in multiple studies to stimulate pathways associated with inflammation, DNA damage and carcinogenesis. Thus, dietary items differ widely in their signaling-pathway effects, with dried fish contaminants shifting the balance toward cancer-promoting molecular events.²⁸

In various studies, four primary categories of contaminants are frequently identified. Firstly, aflatoxins, which are generated by *Aspergillus* species under inadequate drying or storage conditions, represent a significant risk for liver cancer; aflatoxin B1 is especially dangerous. The International Agency for Research on Cancer (IARC) has classified AFB1 as a Group 1 carcinogen, indicating it is recognized to induce cancer in humans. The research revealed aflatoxin concentrations between 0.564 and 9.422 parts per billion (ppb) in fish samples. Although these concentrations fell within the World Health Organization's (WHO) guideline of 10 ppb, 67% surpassed the more stringent European Commission limit of 2 ppb. The Estimated Daily Intake (EDI) of aflatoxins was found to be above the 0.001 g/kg bw/day threshold linked to liver cancer risk, with children estimated at 4.81×10^{-3} g/kg bw/day and adults at 2.41×10^{-3} g/kg bw/day (American Cancer Society, 2011). The Estimated Liver Cancer Risk (ELCR) values indicated that moonfish represented the greatest population-level risk for liver cancer, particularly among children. The Margin of Exposure (MOE) values were high, suggesting a low immediate concern; however, long-term exposure continues to pose a cancer risk. Additionally, Polycyclic Aromatic Hydrocarbons (PAHs), which are produced during the smoke-drying process, such as benzo[a]pyrene, are associated with cancers affecting the lung, bladder, skin, and gastrointestinal tract. Furthermore, cadmium, lead, and mercury three toxic metals present in smoked-dried fish each pose their own carcinogenic threats. Cadmium is most closely associated with lung cancer and exhibits the highest potential for carcinogenicity, especially in children. Lead is linked to kidney cancer and neurological issues due to its effects on DNA integrity. Mercury is implicated in the emergence of cancerous cells through oxidative stress, although no specific type of cancer has been identified. Toxic preservatives and pesticides such as DDT and heptachlor can lead to genetic damage, compromise the immune system, and increase the likelihood of cancer. These concerns are especially troubling for populations that depend on dried fish as a significant part of their diet,

particularly in areas where food safety regulations are not strictly applied. While earlier research minimized these dangers, more recent studies indicate a more definitive correlation between the regular consumption of contaminated dried fish and cancer. This shift in findings suggests that we should view dried fish not only as a traditional food but potentially also as a carcinogenic substance when produced in environments with lax regulations. platforms such as OpenSC developed by BCG digital ventures and WWF Australia are used to trace marine products throughout the supply chain, verifying the sustainability and origin of seafood, these platforms help consumers prevent exposure to carcinogenic risks arising from unsafe or unethical processing practice ^[29,30]

Conclusion

The collective evidence from this review indicates that when dried fish is prepared and stored without proper regulation, which becomes a significant vehicle for carcinogen exposure. Contaminants like aflatoxins, PAHs, heavy metals, pesticide residues, and harmful fungi have been linked with cancers of the liver, lung, kidney, and gastrointestinal tract. In some cases, they are also indirectly connected with cancers through severe opportunistic infections. Irrespective to the common belief that dried fish is a safe preserved food, it poses significant health risks in areas where food safety measures are not enforced. Continuous exposure to these contaminants is a serious public health issue. When dried fish is prepared and stored unsafely, it should be seen as a potential risk of dietary carcinogen. **Although measures have been introduced to reduce this risk such as enforcing regulations, improving drying and storage practices, and educating the public their implementation remains limited. This is largely due to challenges like inadequate infrastructure, reliance on traditional drying methods, poor regulatory enforcement, and socioeconomic dependence on low-cost informal markets. While long-term studies are still needed to strengthen the evidence and define safe exposure limits, the current data is sufficient to justify immediate attention. Strengthening these measures is essential to preserve the nutritional and cultural value of dried fish without compromising public health.**

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